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Cooling Effectiveness of a Modified Cold-Water Immersion Method After Exercise-Induced Hyperthermia

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Context: Recommended treatment for exertional heat stroke includes whole-body cold-water immersion (CWI). However, remote locations or monetary or spatial restrictions can challenge the feasibility of CWI. Thus, the development of a modified, portable CWI method would allow for optimal treatment of exertional heat stroke in the presence of these challenges.

Objective: To determine the cooling rate of modified CWI (tarp-assisted cooling with oscillation [TACO]) after exertional hyperthermia.

Design: Randomized, crossover controlled trial.

Setting: Environmental chamber (temperature = 33.4°C ± 0.8°C, relative humidity = 55.7% ± 1.9%).

Patients or Other Participants: Sixteen volunteers (9 men, 7 women; age = 26 ± 4.7 years, height = 1.76 ± 0.09 m, mass = 72.5 ± 9.0 kg, body fat = 20.7% ± 7.1%) with no history of compromised thermoregulation.

Intervention(s): Participants completed volitional exercise (cycling or treadmill) until they demonstrated a rectal temperature (T_{re}) $\geq$39.0°C. After exercise, participants transitioned to a semirecumbent position on a tarp until either T_{re} reached 38.1°C or 15 minutes had elapsed during the control (no immersion [CON]) or TACO (immersion in 151 L of 2.1°C ± 0.8°C water) treatment.

Main Outcome Measure(s): The T_{re}, heart rate, and blood pressure (reported as mean arterial pressure) were assessed precooling and postcooling. Statistical analyses included repeated-measures analysis of variance with appropriate post hoc *t* tests and Bonferroni correction.

Results: Before cooling, the T_{re} was not different between conditions (CON: 39.27°C ± 0.26°C, TACO: 39.30°C ± 0.39°C; $P = .62$; effect size = –0.09; 95% confidence interval [CI] = –0.2, 0.1). At postcooling, the T_{re} was decreased in the TACO (38.10°C ± 0.16°C) compared with the CON condition (38.74°C ± 0.38°C; $P < .001$; effect size = 2.27; 95% CI = 0.4, 0.9). The rate of cooling was greater during the TACO (0.14 ± 0.06°C/min) than the CON treatment (0.04°C/min ± 0.02°C/min; $t_{15} = -8.84$; $P < .001$; effect size = 2.21; 95% CI = –0.13, –0.08). These differences occurred despite an insignificant increase in fluid consumption during exercise preceding CON (0.26 ± 0.29 L) versus TACO (0.19 ± 0.26 L; $t_{12} = 1.73$; $P = .11$; effect size = 0.48; 95% CI = –0.02, 0.14) treatment. Decreases in heart rate did not differ between the TACO and CON conditions ($t_{15} = -1.81$; $P = .09$; effect size = 0.45; 95% CI = –22, 2). Mean arterial pressure was greater at postcooling with TACO (84.2 ± 6.6 mm Hg) than with CON (67.0 ± 9.0 mm Hg; $P < .001$; effect size = 2.25; 95% CI = 13, 21).

Conclusions: The TACO treatment provided faster cooling than did the CON treatment. When location, monetary, or spatial restrictions are present, TACO represents an effective alternative to traditional CWI in the emergency treatment of patients with exertional hyperthermia.

Key Words: tarp-assisted cooling, heat strain, heat illness, exertional heat stroke

Key Points

- In participants with exercise-induced hyperthermia, tarp-assisted cooling with oscillation provided an adequate cooling rate.
- For treatment of patients with exertional heat stroke, although cold-water immersion remains the criterion standard, tarp-assisted cooling with oscillation may be a feasible alternative when a tub is not available.

Exertional heat stroke (EHS) is one of the most common causes of sudden death among athletes and military personnel.[1–4] The risk increases during the summer months, when ambient temperature and relative humidity increase.[3] Adding protective equipment further compromises normal thermoregulation.[5] The diagnostic criteria for EHS are a core temperature of more than 40.5°C plus alterations in central nervous system function.[1,6] Once a patient is diagnosed, it is critical that core body temperature be reduced to below 38.9°C as quickly as possible to prevent sequelae and to limit the chance of mortality.[6,7]

The National Athletic Trainers' Association recommends whole-body cold-water immersion (CWI) as the best method for treating EHS.[6] Colder water temperatures optimize CWI (ie, provide faster cooling), particularly with continuous water circulation to prevent a barrier of warm water from forming adjacent to the patient.[6,8–12] Oscillating the water supplies a massaging effect to the skin, which increases vasodilation of the peripheral vasculature.[12] Therefore, circulated cold water allows more blood to be cooled at the periphery through conduction and convection and subsequently transported to the core.

Cold-water immersion typically requires a large tub filled with water and ice to be on-site and ready for use during activities. However, Mazerolle et al[13] found that many athletic trainers do not implement this method due to lack of resources and insufficient daily time to maintain the tub. Also, transporting a large tub to certain venues, such as military drills and off-road races, is problematic. Although some[12] contend that patient comfort and cardiovascular status are compromised by CWI, the method consistently demonstrates successful outcomes.[6,8–12,14,15]

A recent review[11] of cooling rates for a variety of modalities identified categories for cooling rates (ie, how long it would take an EHS patient to be cooled appropriately). For efficient cooling to take place in less than 30 minutes, whole-body cooling must be $\geq 0.078°C \cdot min^{-1}$. Typical cooling rates for CWI range between $0.129°C \cdot min^{-1}$ and $0.350°C \cdot min^{-1}$ and produce 100% survival in EHS patients.[8,9,14] In some military and athletic situations, continual rotation of ice-soaked towels or sheets has been successful as an alternative to CWI.[16] However, limited evidence to date supports the use of CWI alternatives for the treatment of exercise-induced hyperthermia.

The tarp-assisted cooling with oscillation (TACO) method was developed to address the challenges of CWI. A plastic tarp held by staff members serves as the container for cold water while the patient sits or lies in the middle. The method is portable and inexpensive (<$20) and has been used successfully in the military and during the 2012 Boston Marathon to treat patients with EHS (C. Troyanos, oral communication, May 2012; M. B. Smith, oral communication, June 2011). Despite anecdotal reports of success with TACO, no studies have been conducted to determine its effectiveness. Therefore, the purpose of our investigation was to determine the cooling rate achievable through the TACO method. We hypothesized that TACO would cool participants at an acceptable rate ($\geq 0.078°C \cdot min^{-1}$) after exercise-induced hyperthermia.

METHODS

Study Design

This research was conducted using a randomized, crossover controlled trial. The study procedures were approved by the institutional review board. The investigation consisted of 2 protocols: exercise and treatment. Our exercise protocol was self-paced for the first trial and matched for the second, and its purpose was to induce hyperthermia. Our treatment protocol was used to compare the treatments in separate trials (1 each with control [CON] and TACO).

Participants

Sixteen participants (9 men, 7 women; age = 26 ± 4.7 years, height = 1.76 ± 0.09 m, mass = 72.5 ± 9.0 kg, body fat = 20.7% ± 7.1%) were recruited from the surrounding community via word of mouth and electronic media for 2 exercise and treatment trials in the heat (1 CON and 1 TACO). After being recruited, participants attended a brief (approximately 30-minute) session covering the informed consent form, medical history form, and details of the study. During this time, participants completed the medical history form to verify that no exclusionary conditions existed: heat exhaustion within the past year or heat stroke within the past 3 months, current illness or musculoskeletal injury, hypertension with a contraindication for vigorous exercise, or cold intolerance.

Once informed consent and medical clearance were obtained, we assessed body composition via dual-energy x-ray absorptiometry. Participants were then scheduled for 2 separate trials at least 1 week apart to prevent heat acclimation. They were asked to refrain from alcohol use and exercise for 24 hours and from caffeine use for 12 hours before each trial. For 24 hours before the first trial, participants recorded their food and fluid intake on a standard diet log and were instructed to match their intake before their second trial. Before instrumentation was applied, participants provided a small urine sample to verify euhydration. Urine specific gravity was measured via refractometry (model Master-SUR/NM scale; ATAGO Co, Ltd, Tokyo, Japan). We obtained each participant's nude body mass (model 349KLX; Health-O-Med Inc, McCook, IL) to confirm euhydration. Participants wore identical clothing to exercise in both trials (men: shorts, short socks and athletic shoes; women: shorts, sports bra or tank top, short socks, and athletic shoes). During cooling, participants were allowed to remove shoes and socks.

Instrumentation

Participants were provided with a heart-rate (HR) strap (model T31; Polar, Lake Success, NY) to wear for the duration of the exercise and treatment. A blood pressure cuff was placed on the upper arm and 3 electrocardiograph electrodes were attached (right and left subclavicular fossa and right anterior axillary line) to allow arterial blood pressure to be measured by auscultation of the brachial artery via electrosphygmomanometry (model Tango+; SunTech Medical, Inc, Raleigh, NC). Participants inserted a rectal thermistor (model RET-1; Physitemp Instruments, Inc, Clifton, NJ) 15 cm beyond the anal sphincter for rectal temperature (T_{re}) measures throughout trials. Participants were educated on perceptual measures (rating of perceived exertion,[17] thirst,[18] thermal sensation,[19] and perceived muscle pain[20]) that were assessed throughout exercise and treatment.

Exercise Protocol. After the instrumentation was applied, the participant entered an environmental chamber (model ETC 01; Can-Trol Environmental Systems, Ltd, Markham, ON, Canada; temperature = 33.4°C ± 0.8°C, relative humidity = 55.7% ± 1.9%). He or she then sat on a chair for 10 minutes, after which baseline values for T_{re}, blood pressure, HR, and perceptual measures were obtained. The blood pressure cuff and electrode leads were removed immediately, and the participant moved to and began exercise on either a bicycle or treadmill. The leads and cuff were removed for participant safety, to prevent their catching on the exercise equipment. During the first trial, each participant self-selected exercise intensity, mode, and duration; these values were recorded by the research staff as sufficient to elevate T_{re} to at least 39°C. This exercise protocol was repeated for the second trial, ensuring a match in metabolic heat production during exercise. The T_{re} and HR were recorded continuously throughout exercise and cooling via computer software (model LabChart7; ADInstruments Inc, Colorado Springs, CO) at 50 Hz during exercise and treatment. Perceptual measures (rating of perceived exertion, thirst sensation, thermal perception, and muscle pain) were taken every 10 minutes during exercise. Exercise was ceased immediately if a participant began to experience signs or symptoms of exertional heat illness or body temperature reached 41°C. During exercise, participants were encouraged to consume ad libitum water heated to 38°C. Once a T_{re} of at least 39°C was reached, they ceased exercise and moved to the cooling portion of the trial.

Treatment Protocol. A standardized transition of 5 minutes was allowed to simulate effective movement of a patient with EHS to a treatment area. Participants moved to the treatment area inside the environmental chamber and assumed a semirecumbent position on a standard tarp (8 × 10 feet [2.5 × 3.1 m]) held at the corners and edges by researchers (minimum of 6). Before starting treatment, the blood pressure cuff and leads were reapplied, and precooling perceptual measures were taken. To begin treatment, the researchers elevated their tarp corners, forming a taco shape.

During the TACO treatment, 151 L of ice water (temperature = 2.1°C ± 0.8°C) from four 37-L water coolers were poured on and around the participant, ensuring that the head and upper chest were above the water. The participant remained immersed for 15 minutes or until T_{re} had returned to 38.1°C (approximately 101°F). After immersion, the participant was assisted in exiting the tarp, toweled dry, and returned to sitting on a chair inside the environmental chamber for 30 minutes. During this latter portion of recovery, T_{re} and HR were recorded every 10 minutes. The participant then exited the chamber to towel completely dry and remove the instrumentation.

During the CON trial, the participant remained semi-recumbent in the dry tarp inside the environmental chamber for 15 minutes. He or she then moved to the chair and sat inside the environmental chamber for 30 minutes before toweling completely dry and removing the instrumentation. For both treatments, T_{re} and HR were monitored continuously during and after treatment. Blood pressure was measured immediately precooling and postcooling. Perceptual measures were taken at the beginning and end of the treatment as well.

Cooling rate was calculated using the following equation:

$$\frac{\text{Pretreatment } T_{re} - \text{posttreatment } T_{re}}{\text{treatment time}}.$$

Blood pressure values were used to calculate mean arterial pressure (MAP) as follows:

$$\frac{1}{3} \times \text{Pulse pressure} + \text{diastolic blood pressure.}$$

Data Analysis

Statistical analysis was completed using SPSS (version 23.0; IBM Corp, Armonk, NY). For all pretreatment and posttreatment measures, we calculated a repeated-measures analysis of variance to assess the effects of treatment between trials. Cooling rates were assessed using a paired-samples t test. An α of $<.05$ was set a priori, and for any statistically significant values, post hoc analysis with appropriate Bonferroni correction was conducted. Effect size (ES) was calculated using G*Power (version 3.1.9.2; Heinrich Heine Universitat, Dusseldorf, Germany). No differences between men and women were identified for any variable, so we combined the data for analysis. Results are presented as mean ± standard deviation.

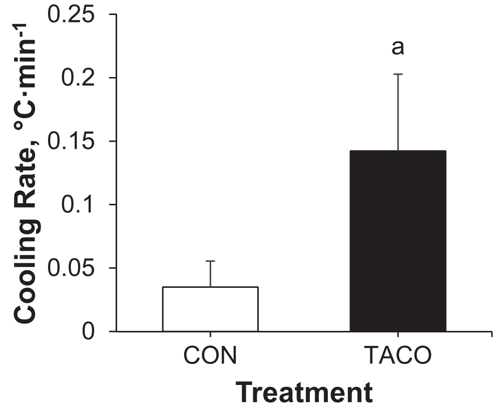

Figure 1. Cooling-rate responses to control (CON) and tarp-assisted cooling with oscillation (TACO) treatment. [a] Indicates greater than CON ($t_{15} = -8.84$, $P < .001$, effect size = 2.21).

RESULTS

The 24-hour diet logs demonstrated no differences between trials (kilocalories: $t_{15} = -0.97$; $P = .35$; ES = 0.24; 95% confidence interval [CI] = –834, 312; protein: $t_{15} = -1.40$; $P = .18$; ES = 0.35; 95% CI = –38, 8; carbohydrates: $t_{15} = -0.85$; $P = .93$; ES = 0.02; 95% CI = –41, 37; fat: $t_{15} = -0.88$; $P = .39$; ES = 0.22; 95% CI = –58, 24, data not shown). Hydration status was not different between trials when measured using either body mass ($t_{15} = 0.03$; $P = .98$; ES = 0.01; 95% CI = –0.4, 0.4) or urine osmolality ($t_{15} = -1.91$; $P = .08$; ES = 0.48; 95% CI = –168, 9). Fluid consumption during exercise was not different between the CON (0.26 ± 0.29 L) and TACO (0.19 ± 0.26 L; $t_{12} = 1.73$; $P = .11$; ES = 0.48; 95% CI = –0.02, 0.14) treatments.

An interaction of time and treatment was demonstrated for T_{re} ($F_{1,15} = 50.40$, $P < .001$; partial $\eta^2 = 0.77$), given that it was similar at the pretreatment time point for both conditions (CON: 39.27°C ± 0.26°C; TACO: 39.30°C ± 0.39°C; $P = .62$; ES = –0.09; 95% CI = –0.17, 0.10) but was lower posttreatment during the TACO (38.10°C ± 0.16°C) compared with the CON (38.74°C ± 0.38°C, $P < .001$; ES = 2.27; 95% CI = 0.43, 0.86) condition. Cooling rate was faster during TACO than during CON ($t_{15} = -8.84$, $P < .001$; ES = 2.21; 95% CI = –0.13, –0.08; Figure 1). The HR was not different between conditions ($F_{1,15} = 1.15$, $P = .30$; partial $\eta^2 = 0.07$; 95% CI = –3, 10), and no interaction was evident ($F_{1,15} = 3.29$, $P = .09$; partial $\eta^2 = 0.18$). However, HR decreased independent of treatment ($F_{1,15} = 182.52$, $P < .001$; partial $\eta^2 = 0.92$; 95% CI = 47, 65) from pretreatment (158.8 ± 17 beats/min) to the end of cooling (102.2 ± 11 beats/min). Change in HR from pretreatment to posttreatment was not different between

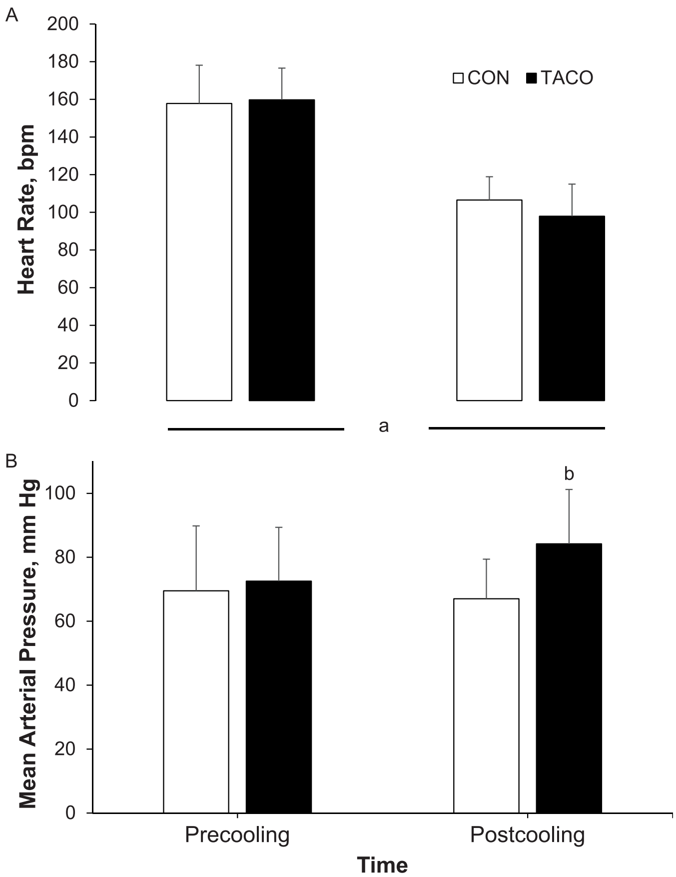

Figure 2. Pretreatment and posttreatment responses for the control (CON) and tarp-assisted cooling with oscillation (TACO) trials. A, Heart-rate responses. B, Mean arterial pressure. [a] Indicates a difference between CON and TACO ($P < .05$). [b] Indicates a difference between pretreatment and posttreatment, regardless of trial ($P < .001$).

CON (–51 ± 19 beats/min) and TACO (–62 ± 22 beats/min; $t_{15} = -1.81$, $P = .09$; ES = 0.45; 95% CI = –22, 2). An interaction of time and treatment was noted for MAP ($F_{1,13} = 12.51$, $P = .004$; partial $\eta^2 = 0.49$; Figure 2), which was greater at the end of treatment in TACO than in CON ($P < .001$; 95% CI = 13, 21).

An interaction of time and treatment was shown for thirst ($F_{1,13} = 19.12$, $P < .001$; partial $\eta^2 = 0.60$), with lower thirst ratings posttreatment in TACO than in CON ($P < .001$; 95% CI = 0.9, 2.3; Figure 3). Thermal sensation also exhibited an interaction of time and treatment ($F_{1,13} = 140.17$, $P < .001$; partial $\eta^2 = 0.92$), with responses lower posttreatment in the TACO compared with the CON ($P < .001$; 95% CI = 2.6, 4.1; Figure 3) condition. In addition, muscle pain demonstrated an interaction effect ($F_{1,13} = 14.48$, $P = .002$; partial $\eta^2 = 0.53$) and increased posttreatment in TACO versus CON ($P = .007$; 95% CI = 0.7, 3.3; Figure 3).

During posttreatment recovery, a significant interaction of time and treatment was present for T_{re} ($F_{3,42} = 5.72$; $P = .02$; partial $\eta^2 = 0.29$; Figure 4). The HR during posttreatment recovery was lower in the TACO than the CON condition regardless of time point ($F_{1,14} = 58.93$, $P < .001$; partial $\eta^2 = 0.81$; 95% CI = 17, 30) and decreased independent of treatment ($F_{3,42} = 16.55$, $P < .001$; partial $\eta^2 = 0.54$), with no interaction of treatment and time ($F_{3,42} = 2.40$, $P = .08$; partial $\eta^2 = 0.15$; Figure 4).

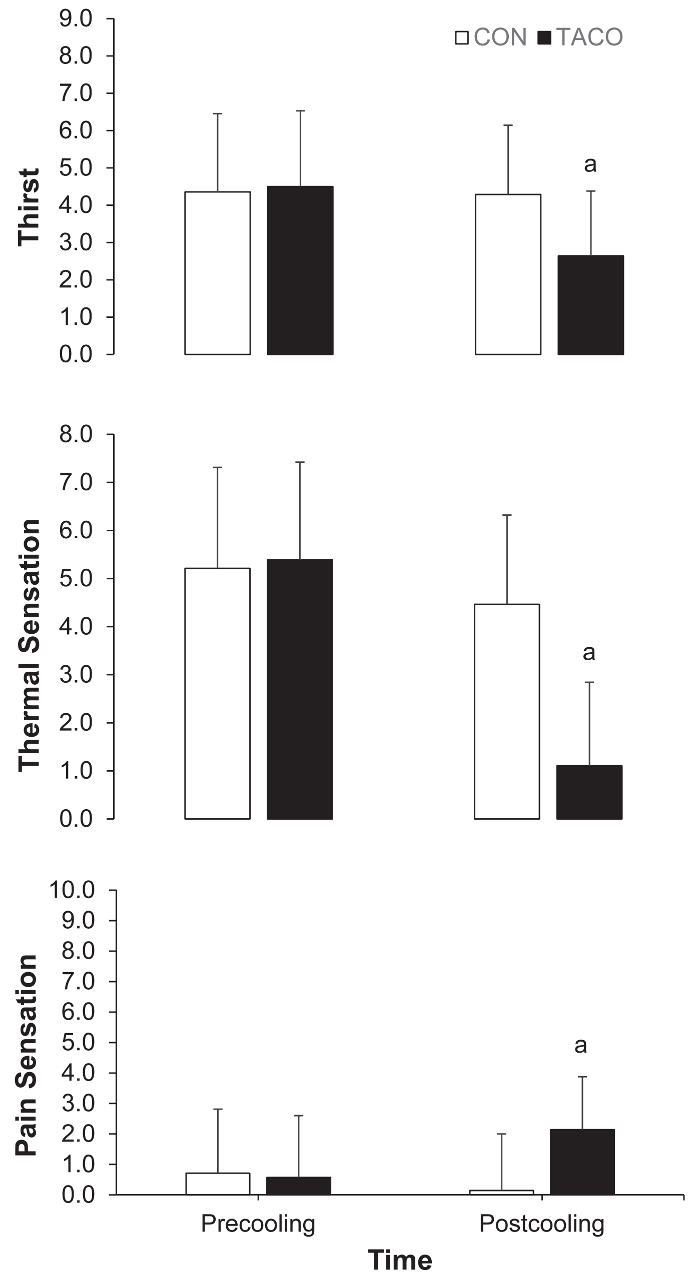

Figure 3. Perceptual measures at pretreatment and posttreatment. [a] Indicates a difference between the control (CON) and tarp-assisted cooling with oscillation (TACO) trials ($P < .05$).

DISCUSSION

We found that using TACO for whole-body cooling of individuals with hyperthermia was more effective than the CON condition. Furthermore, our data established that TACO provided a cooling rate previously deemed acceptable for the treatment of patients with EHS.[11] Decreased body temperature, safe cardiovascular responses, and enhanced perceptual outcomes were evident with TACO after exertional hyperthermia. Our data are important for athletic trainers who work with military and athletic personnel and develop emergency action plans that must

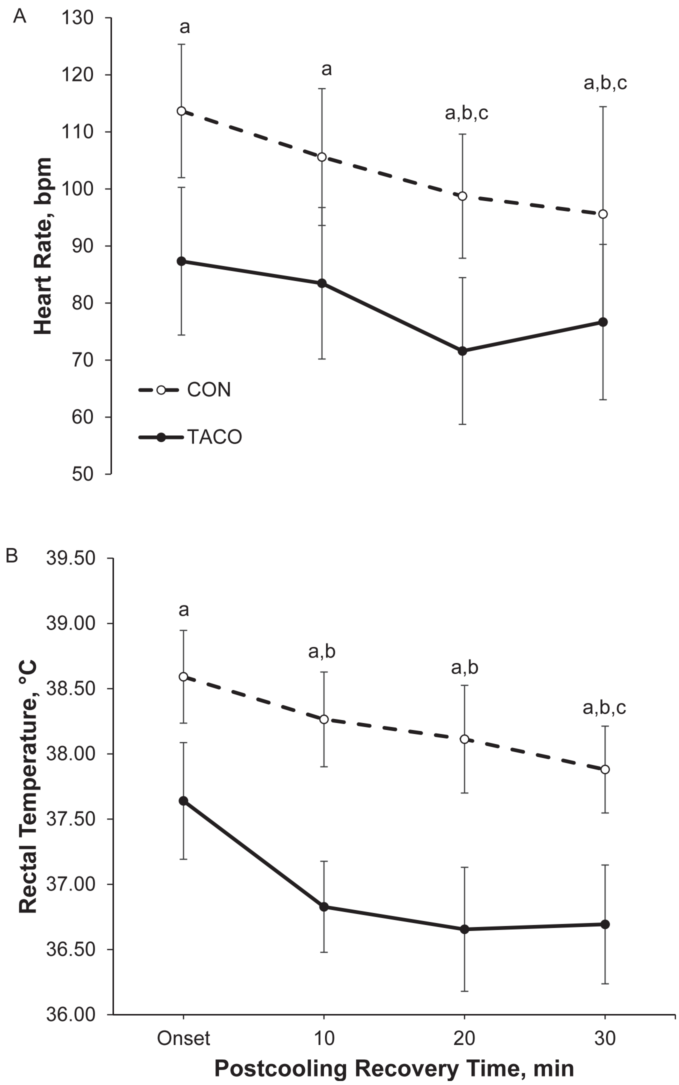

Figure 4. Responses during the postcooling recovery. A, Heart rate. B, Rectal temperature. [a] Indicates a difference from the control (CON) condition ($P < .05$). [b] Indicates a difference from 0 minutes ($P < .05$). [c] Indicates a difference from 10 minutes ($P < .05$).

be executed in remote or restricted areas where traditional CWI using a tub may be impossible.

Though our water temperature (2.1°C ± 0.8°C) was comparable with that of the coldest water used in other studies, our cooling rate was slightly less than the CWI cooling seen elsewhere (up to 0.35°C·min^{-1}).[9] This difference is likely due to the fact that our participants were immersed only to the iliac crest, whereas the Proulx et al[9] participants were immersed in 2°C water up to their clavicles. Even with the limitation that TACO is partial-body CWI, our cooling rate of 0.14°C·min^{-1} would allow for safe cooling of EHS patients within 30 minutes, making this an acceptable (>0.078°C·min^{-1}) modality for emergency treatment.[11]

For ethical reasons, we could not allow individuals to reach core temperatures indicative of EHS (>40.5°C). Strong evidence indicates that the rates at which hyperthermic study participants and patients with EHS cool when using CWI are similar. This point was supported by data[21] from 274 patients with EHS who were cooled with CWI at a mean rate of 0.22°C·min^{-1} ± 0.11°C·min^{-1}. Reports[10] indicate that cooling rates using CWI for hyperthermic participants ranged from 0.129°C·min^{-1} to 0.35°C·min^{-1}. Cooling rates were similar in the literature between patients with EHS and hyperthermic research participants.[10,11,15]

For field use, TACO has potential benefits compared with a traditional CWI tub. Tarps can be easily folded and stored in medical kits and can cost as little as $15, whereas a stock tank costs approximately $200. We found that 151 L of ice water was sufficient to submerge participants at least up to the iliac crest with little variation in water temperature. This amount of water was chosen during pilot testing because most venues have at least 4 coolers of ice water available in case of emergency. To use this method in the field, we recommend having at least 6 people to assist in holding the tarp because 151 L of water weighs approximately 150 kg, independent of the patient's body weight. As with all emergency action plans, medical staff and all individuals who may be involved in emergency procedures at the venue should practice this method before an actual emergency occurs. Furthermore, practice should be conducted with the recognition that many patients with EHS become combative due to central nervous system dysfunction. Standing close to the patient helps to maintain the water level and allows the tarp to be oscillated efficiently with repeated knee bends to maintain water circulation. Although we did not quantify the amount of water circulation in the current study, having the same researchers for each trial ensured consistent oscillations. In addition, given our acceptable cooling rate, this method provided sufficient movement to facilitate cooling.

Our cooling rates using TACO were slightly better than those previously identified using constantly rotating towels or sheets for heat-illness treatment.[16] When ice-soaked towels were continually rotated, Armstrong et al[16] identified a mean cooling rate of 0.11°C·min^{-1} in 7 patients with EHS. Other anecdotal reports have described constant rotation of ice sheets as successful in treating heat casualties in the military. However, this treatment option requires further research documentation to be considered evidence based. One advantage of rotating ice-soaked towels or sheets is that the treatment requires less cold water than our TACO trial (approximately 38 L versus 151 L, respectively). This factor may decrease the feasibility of TACO when cold water is in short supply, yet it may also be a limiting factor in the cooling rate. The more water in contact with the patient's skin, the better the cooling, and less water used in treatment may compromise cooling efficiency.[10,12] On the basis of our data, TACO is recommended over ice-sheet rotations. Future researchers should investigate and document the efficacy of ice-sheet rotations.

Our participants had similar body types, so we suggest future researchers use this method on a more heterogeneous sample population to ensure effectiveness for all body types and provide the best recommendations for use in the field. For example, previous researchers[10,21] have shown that differences in body surface area (BSA) and the ratio of BSA to lean body mass affect cooling rates in hyperthermic individuals. Because CWI relies on conductive and convective heat loss, it follows that a greater BSA allows more contact with the cold water and, therefore, a greater amount of heat loss can be achieved. Even though individuals with a larger BSA relative to body mass index may have greater adiposity, this had a limited effect on cooling rate.[21]

The HR responses to water immersion after exercise vary from nonsignificant decreases in thermoneutral water to significant decreases in cold water (<16°C).[22,23] Although our change in HR was not different between the CON and TACO conditions, the greater MAP (Figure 2) in TACO postcooling indicates better maintenance of cardiac function during TACO than during the CON condition. During CON, the participants were semirecumbent and not moving for 15 minutes; blood likely pooled in the lower extremities and delayed recovery. Furthermore, Kenny et al[24] demonstrated reductions in sweating and skin blood flow while esophageal temperature was still elevated after exercise. These reductions occur from nonthermal contributions leading to impaired heat loss. Given that our participants' MAP decreased similarly at the end of treatment, it is possible that these perturbations in heat-loss mechanisms may have led to the slower cooling rates in our CON trial.

Perceptual measures provided insight into how our participants felt during cooling. Thirst was rated lower postcooling in TACO than in CON, which is likely due to the maintenance of blood pressure and circulation during immersion. Because we used an extreme water temperature, we expected to find decreased thermal sensation with TACO compared with CON. Our identified increase in muscle pain with cooling may reflect participants' difficulty differentiating between muscular and cutaneous pain sensation caused by the water temperature. Some of our participants began to shiver during cooling as well, which may have increased muscular pain.

CONCLUSIONS

The purpose of our study was to examine the cooling rate of TACO after exercise-induced hyperthermia. Given the resulting cooling rate of $0.14°C·min^{-1} \pm 0.06°C·min^{-1}$, TACO is an acceptable method of reducing an individual's core temperature in an appropriate amount of time for emergency treatment of EHS. Though CWI in a traditional tub remains the criterion standard for treatment of patients with EHS, TACO could be included in emergency action plans for remote venues or in situations where the use of a CWI tub is not immediately feasible.

REFERENCES

1. Carter R III, Cheuvront SN, Williams JO, et al. Epidemiology of hospitalizations and deaths from heat illness in soldiers. *Med Sci Sports Exerc*. 2005;37(8):1338–1344.
2. Bedno SA, Urban N, Boivin MR, Cowan DN. Fitness, obesity, and risk of heat illness among army trainees. *Occup Med (Lond)*. 2014; 64(6):461–467.
3. Kerr ZY, Casa DJ, Marshall SW, Comstock RD. Epidemiology of exertional heat illness among US high school athletes. *Am J Prev Med*. 2013;44(1):8–14.
4. Yard EE, Gilchrist J, Haileyesus T, et al. Heat illness among high school athletes—United States, 2005–2009. *J Safety Res*. 2010;41(6): 471–474.
5. Armstrong LE, Johnson EC, Casa DJ, et al. The American football uniform: uncompensable heat stress and hyperthermic exhaustion. *J Athl Train*. 2010;45(2):117–127.
6. Casa DJ, DeMartini JK, Bergeron MF, et al. National Athletic Trainers' Association position statement: exertional heat illnesses. *J Athl Train*. 2015;50(9):986–1000.
7. Heled Y, Rav-Acha M, Shani Y, Epstein Y, Moran DS. The "golden hour" for heatstroke treatment. *Mil Med*. 2004;169(3):184–186.
8. Costrini A. Emergency treatment of exertional heatstroke and comparison of whole body cooling techniques. *Med Sci Sports Exerc*. 1990;22(1):15–18.
9. Proulx CI, Ducharme MB, Kenny GP. Effect of water temperature on cooling efficiency during hyperthermia in humans. *J Appl Physiol (1985)*. 2003;94(4):1317–1323.
10. Friesen BJ, Carter MR, Poirier MP, Kenny GP. Water immersion in the treatment of exertional hyperthermia: physical determinants. *Med Sci Sports Exerc*. 2014;46(9):1727–1735.
11. McDermott BP, Casa DJ, Ganio MS, et al. Acute whole-body cooling for exercise-induced hyperthermia: a systematic review. *J Athl Train*. 2009;44(1):84–93.
12. Casa DJ, McDermott BP, Lee EC, Yeargin SW, Armstrong LE, Maresh CM. Cold water immersion: the gold standard for exertional heatstroke treatment. *Exerc Sport Sci Rev*. 2007;35(3):141–149.
13. Mazerolle SM, Pinkus DE, Casa DJ, et al. Evidence-based medicine and the recognition and treatment of exertional heat stroke, part II: a perspective from the clinical athletic trainer. *J Athl Train*. 2011; 46(5):533–542.
14. Demartini JK, Casa DJ, Stearns R, et al. Effectiveness of cold water immersion in the treatment of exertional heat stroke at the Falmouth Road Race. *Med Sci Sports Exerc*. 2015;47(2):240–245.
15. Hadad E, Moran DS, Epstein Y. Cooling heat stroke patients by available field measures. *Intensive Care Med*. 2004;30(2):338.
16. Armstrong LE, Crago AE, Adams R, Roberts WO, Maresh CM. Whole-body cooling of hyperthermic runners: comparison of two field therapies. *Am J Emerg Med*. 1996;14(4):355–358.
17. Borg G. Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med*. 1970;2(2):92–98.
18. Engell DB, Maller O, Sawka MN, Francesconi RN, Drolet L, Young AJ. Thirst and fluid intake following graded hypohydration levels in humans. *Physiol Behav*. 1987;40(2):229–236.
19. Toner MM, Drolet LL, Pandolf KB. Perceptual and physiological responses during exercise in cool and cold water. *Percept Mot Skills*. 1987;62(1):211–220.
20. Cook DB, O'Connor PJ, Eubanks SA, Smith JC, Lee M. Naturally occurring muscle pain during exercise: assessment and experimental evidence. *Med Sci Sports Exerc*. 1997;29(8):999–1012.
21. Lemire BB, Gagnon D, Jay O, Kenny GP. Differences between sexes in rectal cooling rates after exercise-induced hyperthermia. *Med Sci Sports Exerc*. 2009;41(8):1633–1639.
22. Wilcock IM, Cronin JB, Hing WA. Physiological response to water immersion. *Sports Med*. 2006;36(9):747–765.
23. DeMartini JK, Ranalli GF, Casa DJ, et al. Comparison of body cooling methods on physiological and perceptual measures of mildly hyperthermic athletes. *J Strength Cond Res*. 2011;25(8):2065–2074.
24. Kenny GP, Gagnon D, Jay O, McInnis NH, Journeay WS, Reardon FD. Can supine recovery mitigate the exercise intensity dependent attenuation of post-exercise heat loss responses? *Appl Physiol Nutr Metab*. 2008;33(4):682–689.

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